Teleconnections of Middle East Climate - Interim Report

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The overall goal of our Middle East Water Vapor Initiative (MEWI) was to investigate the remote and local forcing mechanisms on precipitation and its variations over the Middle East region. There is significant reason to believe that variations in precipitation climatology in the region are related to climate anomalies in other parts of the world. Dating back to 1932, Walker and Bliss (1932) found that wintertime temperatures anomalies in the Greenland-Labrador area and in the Middle East are negatively correlated with those over the eastern United States and northwestern Europe by using an index consisting of a linear combination of surface temperature and sea level pressure at selected stations. This pattern is referred to as the well known North Atlantic Oscillation. In order to study the relationships between precipitation over the Middle East and other climate and circulation parameters over the globe, several long-term climate data sets were obtained. First, in order to understand the regional and local precipitation climatology, rainfall records from 15 selected stations in Israel, Lebanon, Syria, and Jordan were studied. Second, the NCEP reanalysis data set (Kalnay et al. 1996) was obtained. The current reanalysis data set spans 13 years although preparation of reanalysis fields back to 1957 are in progress. Additionally, simultaneous correlation and principal component analysis was used with the reanalysis data to study teleconnectivity between dominant climate events and Middle East weather. The limited funds available for such a study and the rapid response requested of the various investigators allowed for only a quick assessment of the data and the proposed methodology. A brief summary of these results is presented below.

Figure 1 presents the names and locations of 15 Middle East weather stations with precipitation records spanning over 50 years. The station density is quite fine in some regions but sparse in others. The orography of the region is such that most inland locations are elevated and on the lee-side of the mountains. Figure 2 shows the annual climatological mean and standard deviation of precipitation for these stations. There is considerable variability in the annual amounts over the relatively small geographical region (about 150,000 km^2) of Israel, Syria, and Jordan.

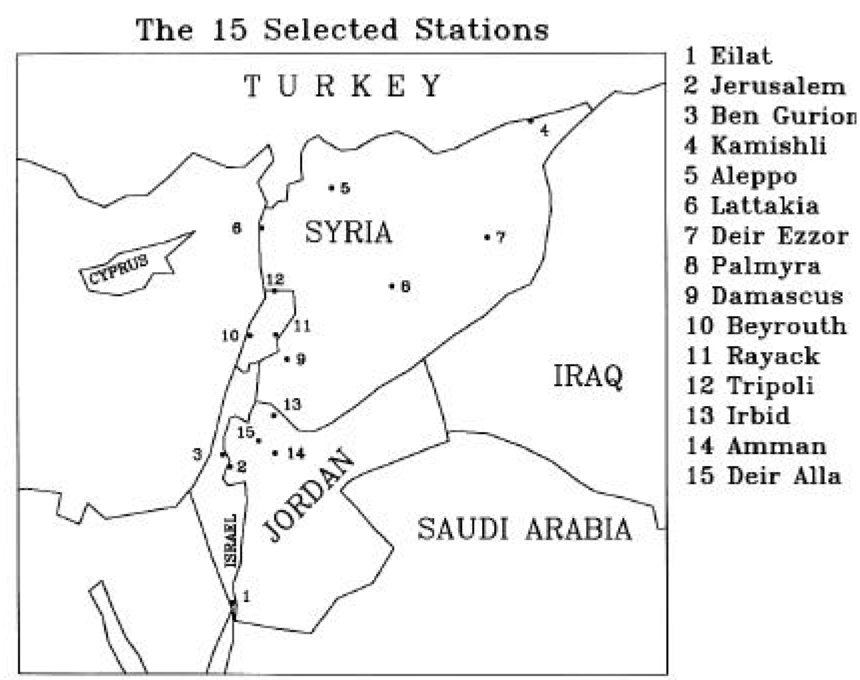

Figure 1. Middle East weather stations used in the study.

The spatial distribution of precipitation over the region is affect by the stations proximity to the sea and therefore its position with respect the inland terrain. Most of the contribution to the annual precipitation value is from the winter season (December, January, and February) when, in general, two-thirds of the annual rainfall occurs.

Our analysis also reveals that there is a relatively low correlation between rainfall amounts for the various stations over the region although rainfall amounts from coastal stations are inter-related. This indicates that while large scale synoptic patterns control seasonal rainfall patterns, local terrain plays a very important factor in the spatial distribution and amount of precipitation. This is consistent with the numerous investigations by the Israel Meteorological Service (Goldreich 1976, 1987, 1992; and Isakasa 1996). Figure 3 shows an example of the seasonal and interannual variability of precipitation for Jerusalem. Most of the rainfall occurs in the winter season with little or no rain occurring in the summer.   This pattern is quite typical of all stations in the Middle East. Although the transition seasons (April/May and October/November) exhibit only moderate amounts of precipitation, the variability of precipitation during these periods can be quite large (standard deviation bars in Figure 3). Significant climate events such as the El Nino Southern Oscillation (ENSO) may provide much of the explanation for this variability.

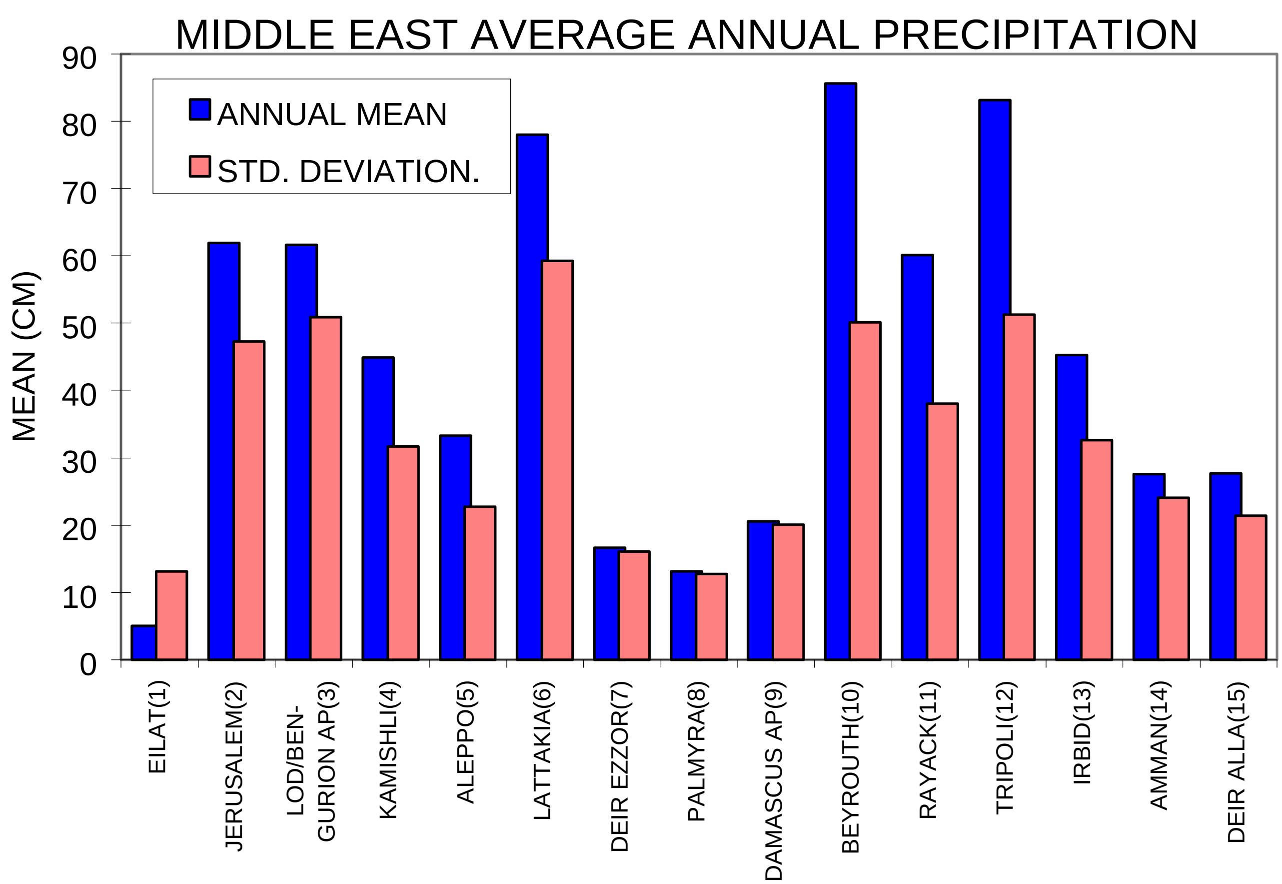

Figure 2. Mean annual precipitation for 15 selected stations in the Middle East. The length of the over record varies between stations but is greater than 50 years in all cases. The variation in the annual mean is indicated by the standard deviation.

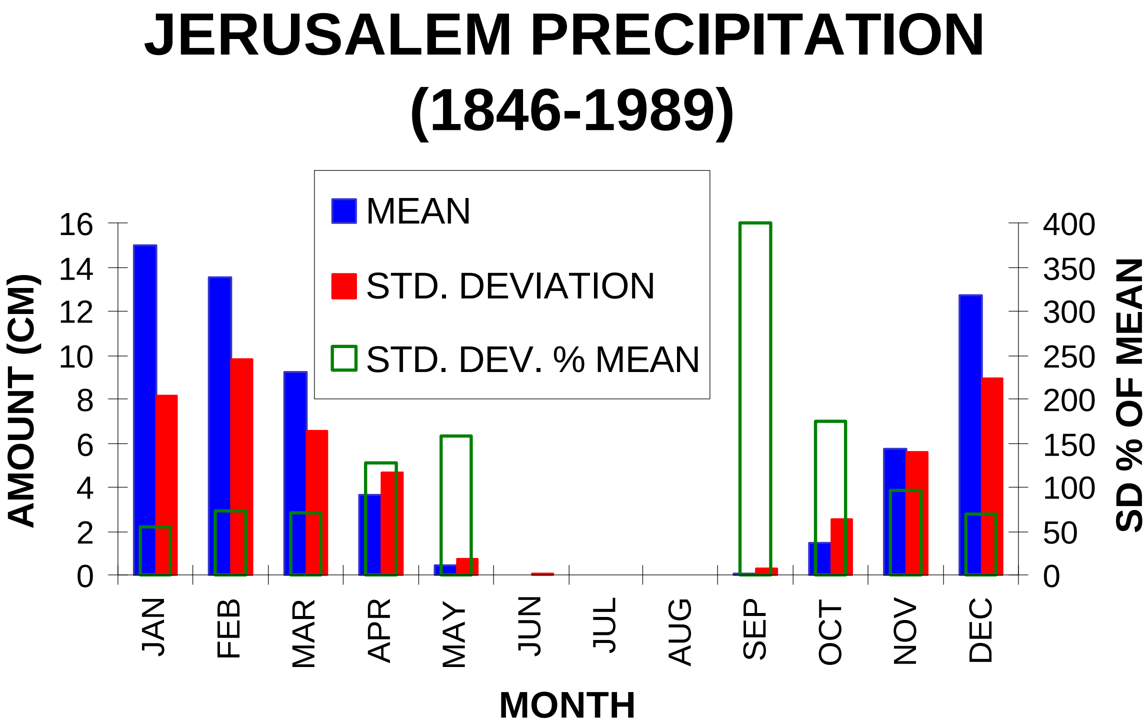

Figure 3. Mean monthly precipitation for Jerusalem. The red bars indicate the standard deviation from the mean. The open green bars indicate the amount of inter-annually variability as a function of the annual mean, expressed in percent on the right axis.

Teleconnection is commonly referred to as the significant simultaneous correlation between temporal fluctuations in meteorological parameters at widely separated points on Earth. It is calculated by determining the correlation of the time series of data at a given point to every other point in the field. This can be done for several points or for a whole field or grid of points. In the latter case, a teleconnectivity map is produced which shows the significance of the connectivity over a large region (Chang 1991, 1983). An example of this is presented in Figure 4 for the warm season sea level pressure derived from the 13 year (1982-1994) NCEP/NCAR reanalysis data. The orange and red shaded areas indicate the regions of highest correlation (values in percent). The lines connecting correlation centers indicate the regions of teleconnectivity. This summer-time sea level pressure analysis shows no significant teleconnection patterns with the Middle East region. An analysis of the summer-time sea level pressure, 500 MB and 200 MB climatological mean and stationary wave patterns revealed equatorward flow at the surface over the eastern Mediterranean area. The upper-level flow patterns are weak with a strong ridge of high pressure providing subsiding motion over the region and blocking the penetration of synoptic systems form the north. An examination of the teleconnection patterns of sea-level pressure, precipitation, as well as other thermodynamic fields will be more useful in the winter and transition seasons where the Middle East region is more influenced by larger-scale synoptic disturbances.

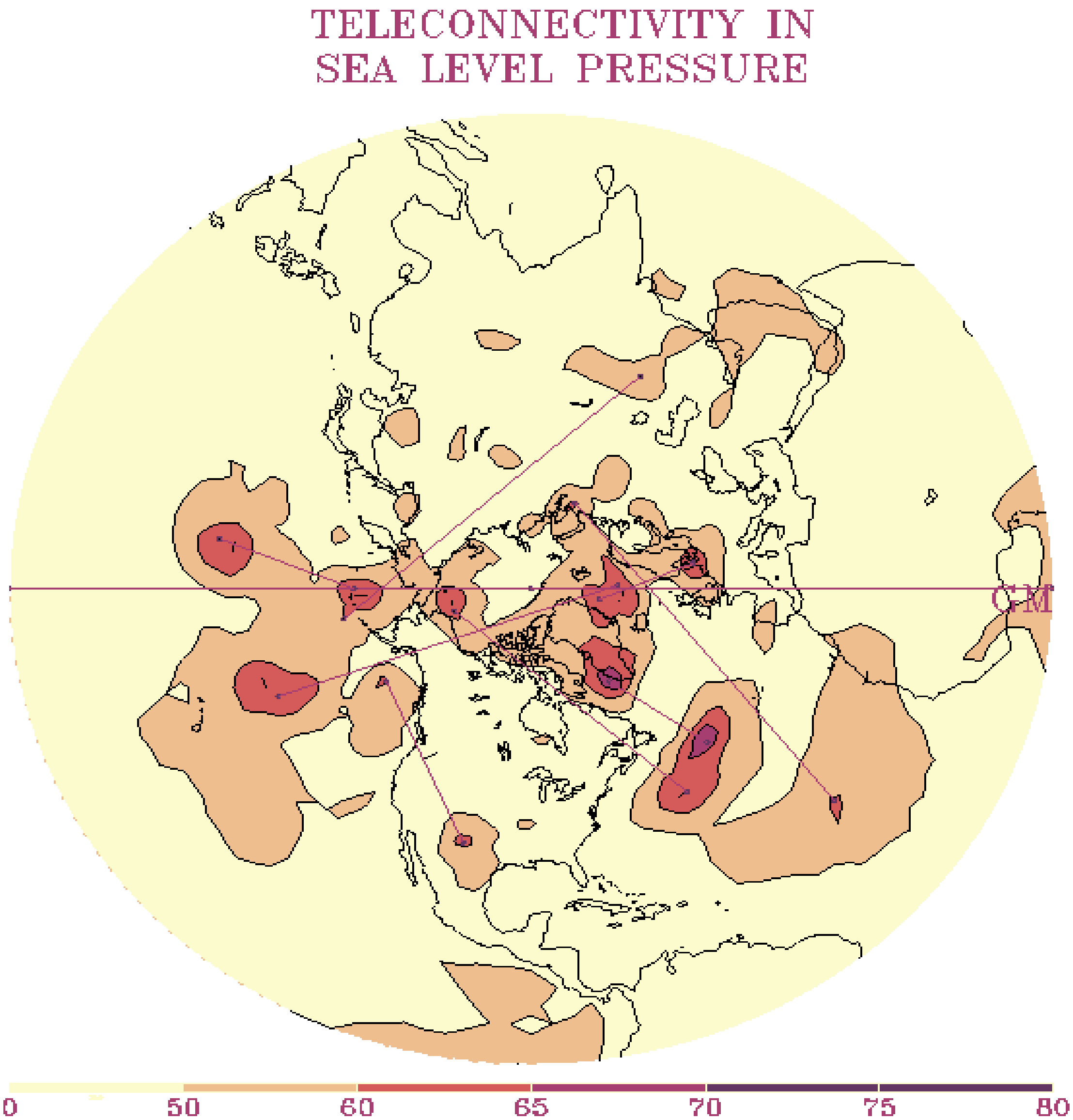

Figure 4. Teleconnectivity patterns for northern hemisphere warm season sea level pressure. Colors indicates correlation values times 100. Lines connecting correlation centers indicate the teleconnection between the regions.

Another way to look at the teleconnectivity patterns of hybrid fields (multiple parameters time series) is to use principal component analysis (Chang 1986). A rotated principal component solution refers to a linear transformation of the initial principal components utilizing the varimax method. The varimax method maximizes the variance of the squared correlation coefficients between each rotated principal component and each of the original time series. The principal component solution maximizes the sum of the squared correlation coefficients. Maximizing the variance causes the loadings of the rotated principal components to be widely distributed with a few large loadings and many close to zero. Hence the rotation of the principal components using varimax method increases the discrimination among the loadings and makes them easier to interpret. This method was explored but not pursued in this initial research because of the limited funding for the project.

Future work should include an analysis of winter-time and transitional seasons of teleconnectivity patterns.

- Apply teleconnectivity and EOF analysis of single fields to winter season
- Extend analysis to hybrid fields (multiple parameters of sea level pressure, sea surface temperature, 500/200 mb height, and precipitation
- Based on insight gained from the above analyses, re-compute results with longer period reanalysis data to incorporate well know periods of climate variability including the ENSO events of the 1970's.
- Study the relationship of the 1997/1998 ENSO event on precipitation patterns over the middle East

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